INSTRUCTION MANUAL

CAPACITANCE STANDARDS

TYPE 76-1A

BOONTON ELECTRONICS CORPORATION

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CAPACITANCE STANDARDS

TYPE 75-1A

CHAPTER I

INTRODUCTION

The Model 76-1A Three-Terminal Capacitance Standards are rugged, stable, fixed capacitors designed primarily for the calibration and standardization of precision capacitance bridges.

They are available in any desired value from 0.01 pF to 1000 pF. The actual capacitance value, directly traceable to NBS, is specified at 100 kHz and 23° C. Also specified are corrections to determine the capacitance at any frequency up to 1 MHz and at any temperature in the range of 18° C to 30° C.

The capacitor elements use an air dielectric for standards below 35 pF. For 35 pF and higher standards, the dielectric is stabilized silvered mica. To assure the highest accuracy, the standards have been designed with low series inductance and low shunt capacitance from each terminal to case ground. They are sealed in non-magnetic metal cases with BNC receptacles. Each standard is subjected to repeated heat cycling and testing to assure long term stability.

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CHAPTER II

SPECIFICATIONS

Capacitance Range:	Any value between 0.01 pF and 1000 pF. Each standard is set to within 0.5% of the value ordered. The exact value to four significant figures is stamped on the case nameplate and recorded in an individual certificate.
Frequency Range:	Capacitance specified at 100 kHz, useable to 1 MHz. Corrections for the effect of series inductance in the standard and interconnecting cables are necessary as the frequency approaches 1 MHz (see section 3.3).
Accuracy:	At 100 kHz and 23° C (traceable to NBS) 1 pF to 1000 pF: $\pm[0.1 + 0.05/\sqrt{C_{(pF)}}]\%$ 0.1 pF to 1 pF: $\pm[0.12 + 0.03/C_{(pF)}]\%$ 0.01 pF to 0.1 pF: $\pm 0.042/C_{(pF)}\%$
Temperature Coefficient:	Individually specified in a certificate with each standard. Typically less than 50 ppm/°C for all values above 2 pF, less than 150 ppm/ °C below 2 pF.

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1 pF to 1000 pF: $\pm(1.1 + 0.05\sqrt{C_{(pF)}})$%

0.1 pF to 1 pF: $\pm(0.12 + 0.03/C_{(pF)})$%

0.01 pF to 0.1 pF: $\pm 0.042/C_{(pF)}$%

Temperature Coefficient: Individually specified in a certificate with each standard. Typically less than 50 ppm/°C for all values above 2 pF, less than 150 ppm/°C below 2 pF.

Stability:	500 pF to 1000 pF:	0.01%/year
	2 pF to 500 pF:	0.02%/year
	0.1 pF to 2 pF:	0.05%/year
	0.01 pF to 0.1 pF:	0.1%/year
Series Inductance:	See Figure 2.	
Shunt Capacitance:	See Figure 7.	
Maximum Voltage:	400 V (dc + peak ac)	
Connections:	BNC receptacles on 1.5 inch centers	
Case:	Sealed, non-magnetic	
Dimensions:	4" L, 3" W, 3" H	

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CHAPTER III

OPERATION

3.1 Connection of a 76-1A Standard to a Boonton Electronics Bridge

Proper techniques are required to transfer the accuracy of a Standard with minimum uncertainty. Referring to Figure 1:

a. Connect both cables to the bridge and the LO cable to one receptacle of the standard.

b. Balance the bridge.

c. Connect the HI cable to the other receptacle of the standard and measure the capacitance.

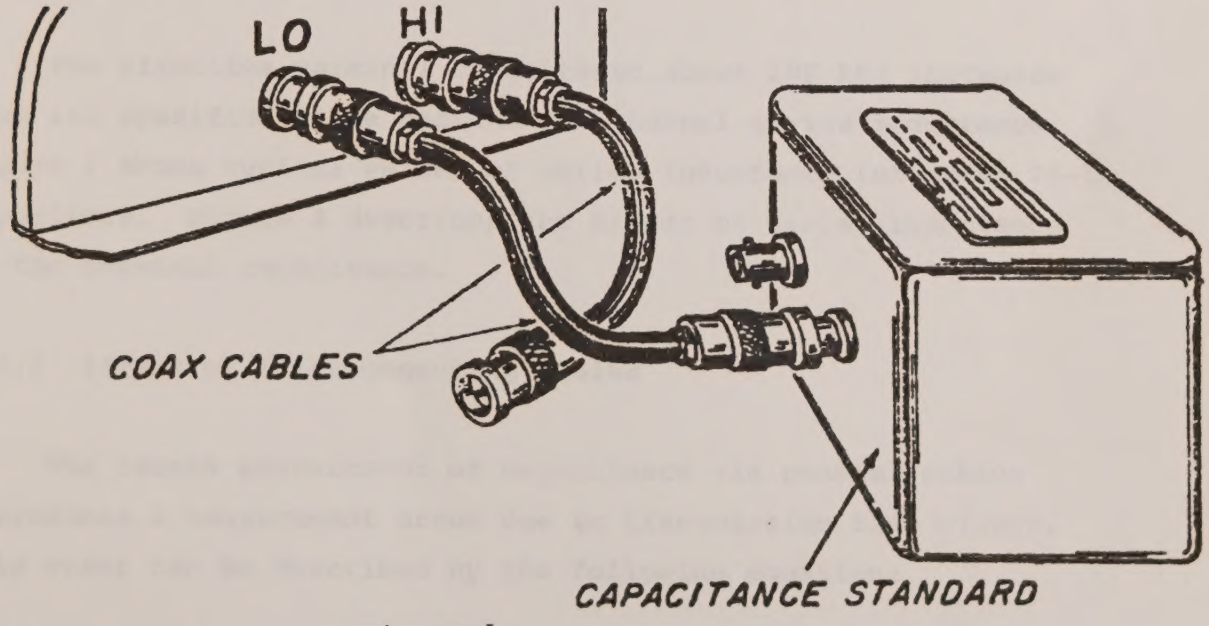

Figure 1

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Figure 1

3.2 Use of a 76-1A Standard at 100 kHz

If the Standard is used at 100 kHz and 23° C, the specified capacitance value can be used directly. If the ambient temperature departs significantly from 23° C, correction should be made to the capacitance value according to the specified temperature coefficient recorded in the individual certificate.

3.3 Use of a 76-1A Standard above 100 kHz

When Standards are used above 100 kHz, corrections must be made to the specified capacitance value due to internal series inductance. In addition, the effect of the interconnecting cables must be considered.

3.3.1 Effect of Series Inductance

The effective terminal capacitance above 100 kHz increases from its specified value because of internal series inductance. Figure 2 shows typical values of series inductance for Model 76-1A Capacitors. Figure 3 describes the effect of series inductance on the terminal capacitance.

3.3.2 Effect of Interconnecting Cables

The remote measurement of capacitance via coaxial cables introduces a measurement error due to transmission line effect. This error can be described by the following equation:

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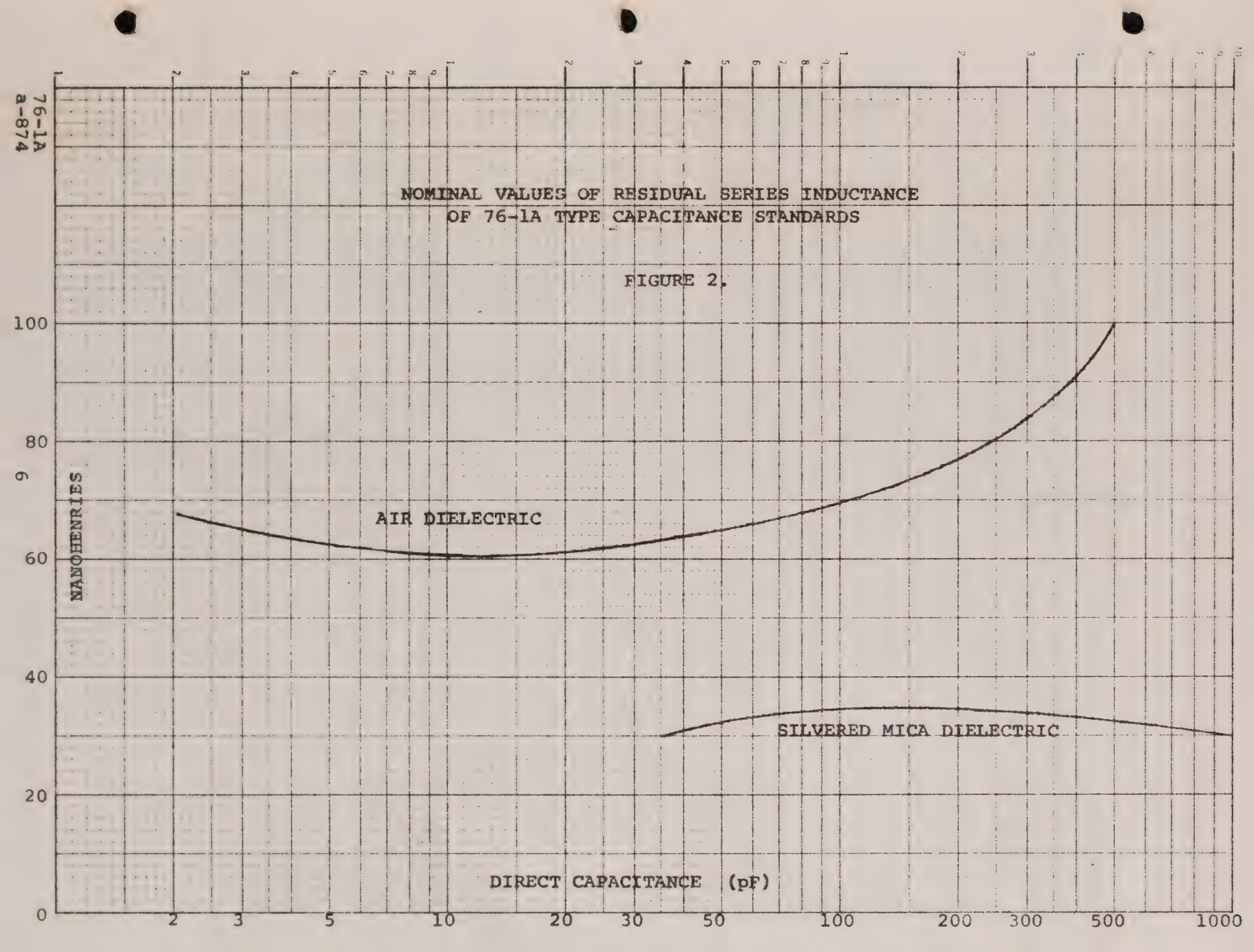
NOMINAL VALUES OF RESIDUAL SERIES INDUCTANCE
OF 76-1A TYPE CAPACITANCE STANDARDS

FIGURE 2.



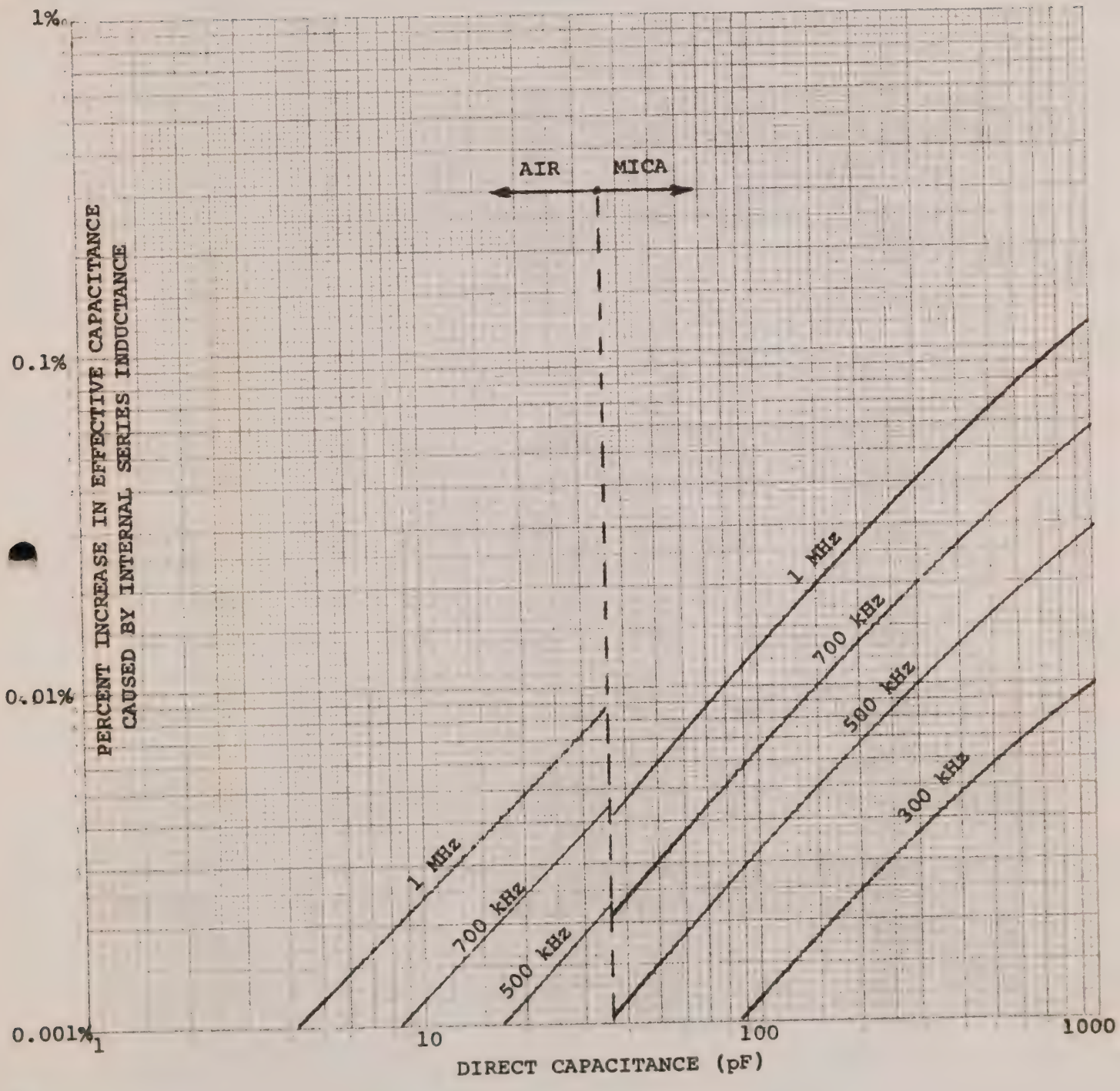


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FIGURE 3.

$$C_m/C = \frac{1+j\omega Cr}{(\cos\beta l - \omega C Z_o \sin\beta l)^2 \left[1+j\,\frac{\omega Cr\cos\beta l + (\sin\beta l) r/Z_o}{\cos\beta l - \omega C Z_o \sin\beta l}\right]}$$

Where βl = electrical length from the BNC receptacles of the Standard to the point of measurement (each of the two cables is assumed equal in length).

C_m = measured capacitance

C = actual capacitance

Z_o = characteristic impedance of cables

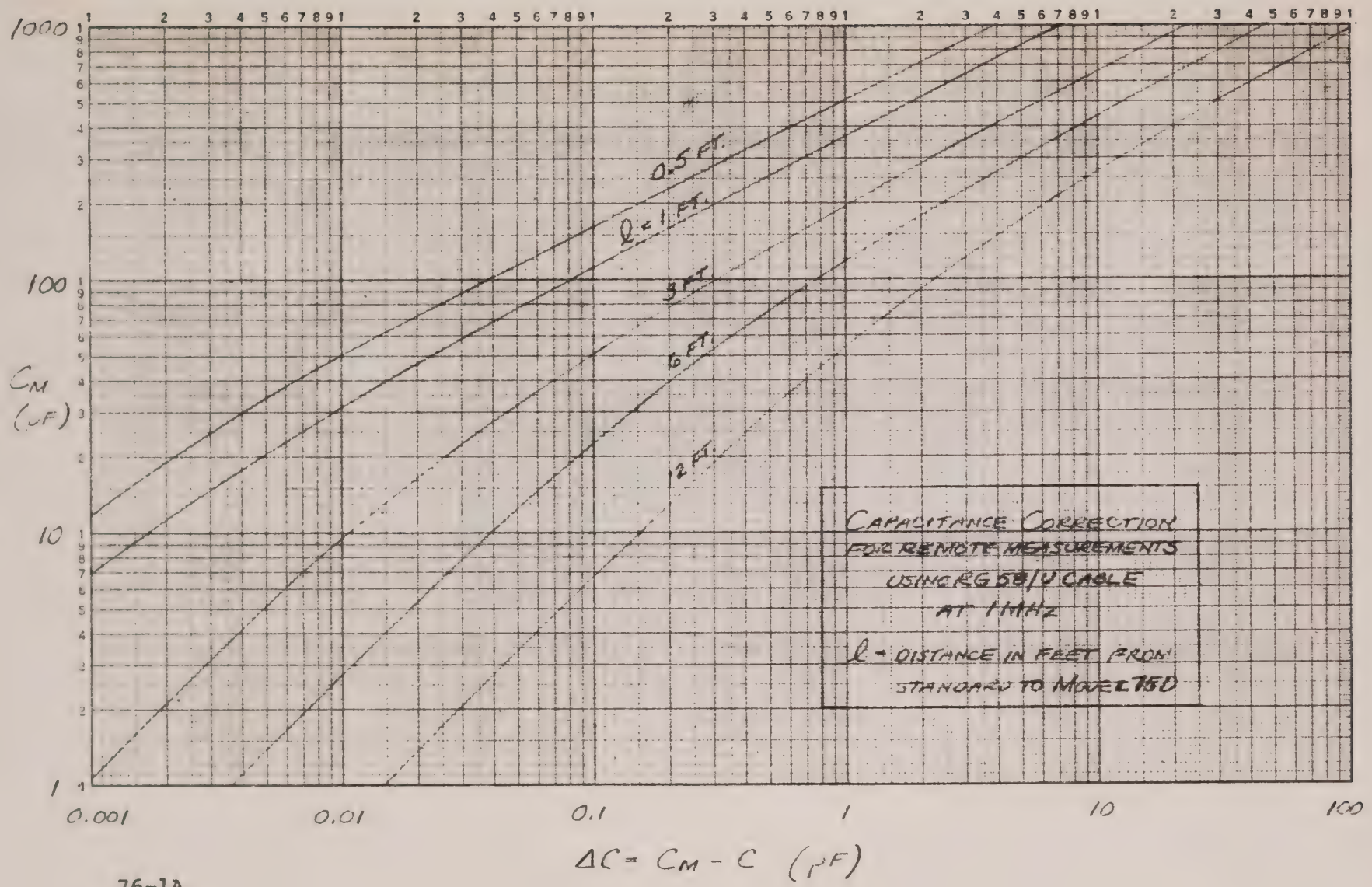
r = terminating resistance at the high terminal of the measuring instrument

NOTE: At 1 MHz, RG58/U cable has a Z_o = 57.5 Ω and a relative velocity of propagation of 63.5%.

Figure 4 shows this equation plotted at 1 MHz for various lengths of RG58/U cable connected to a BEC Model 75D Bridge (r = 12 Ω); Figure 5 should be used when the CS Standard is connected to a Model 72 Capacitance Meter (r = 140 Ω, 1 and 3 pF fs; r = 7 Ω, 10 and 30 pF fs; r = 1 Ω, 100 pF and above). In Figure 5 the error is not shown for the two lower ranges of 12 foot lengths of cable as the capacitive loading of the HI test terminal is excessive for lengths of RG58/U greater than about 3.5 feet, and lengths of about 8 feet for the 10 pF and 30 pF ranges.

It is imperative that the shields of <u>both</u> ends of the coaxial cables be tied together with a low resistance, low inductance strap for the correction equation and curves to be valid.

Figure 4.


1000
100
10
1
C_M (pF)
0.5 FT.
1 FT.
3 FT.
6 FT.
12 FT.
CAPACITANCE CORRECTION
FOR REMOTE MEASUREMENTS
USING RG58/U CABLE
AT 1 MHz
ℓ = DISTANCE IN FEET FROM
STANDARD TO MODEL 750
0.001
0.01
0.1
1
10
100
$\Delta C = C_M - C$ (pF)

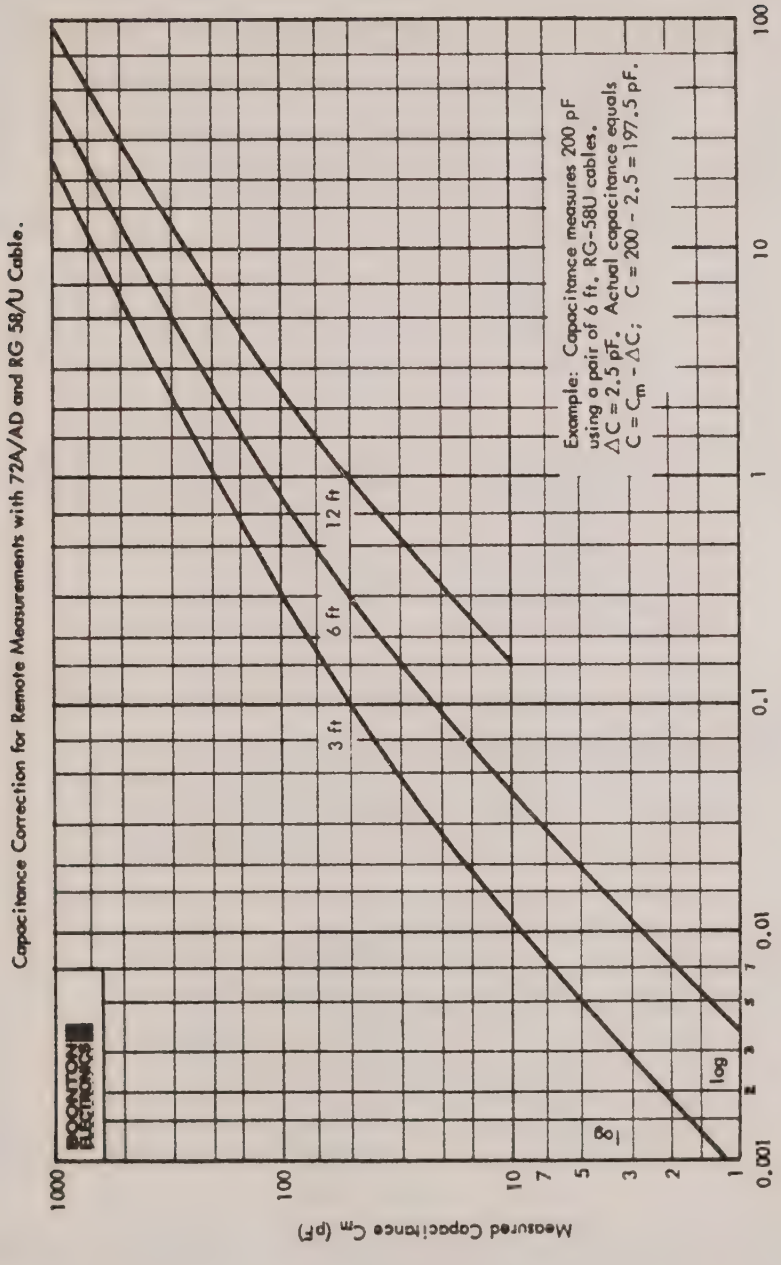


Figure 5. Capacitance Correction

For short lengths of cable, a reasonable correction may be made based upon the effect of the series inductance of both lengths of cable. The measured capacitance, C_m, of a specimen will differ from the true capacitance, C. The error will be seen as an apparent increase in capacitance in accordance with the following expression:

$$C_m = \frac{C}{1 - \omega^2 LC} = \frac{C}{1 - (X_L/X_C)}$$

Or, if the true capacitance is required:

$$C = \frac{C_m}{1 + \omega^2 LC_m} = \frac{C_m}{1 + (X_L/X_{C_m})}$$

Where L = the combined series inductance of BOTH lengths of of connecting cables and the inductance of the sample (generally small with respect to the cable's inductance).

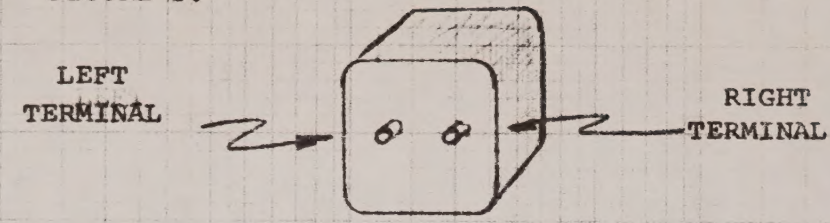
As an approximation, the inductance of RG58/U cable (with shields common at both ends) is about 0.091 μH/ft.

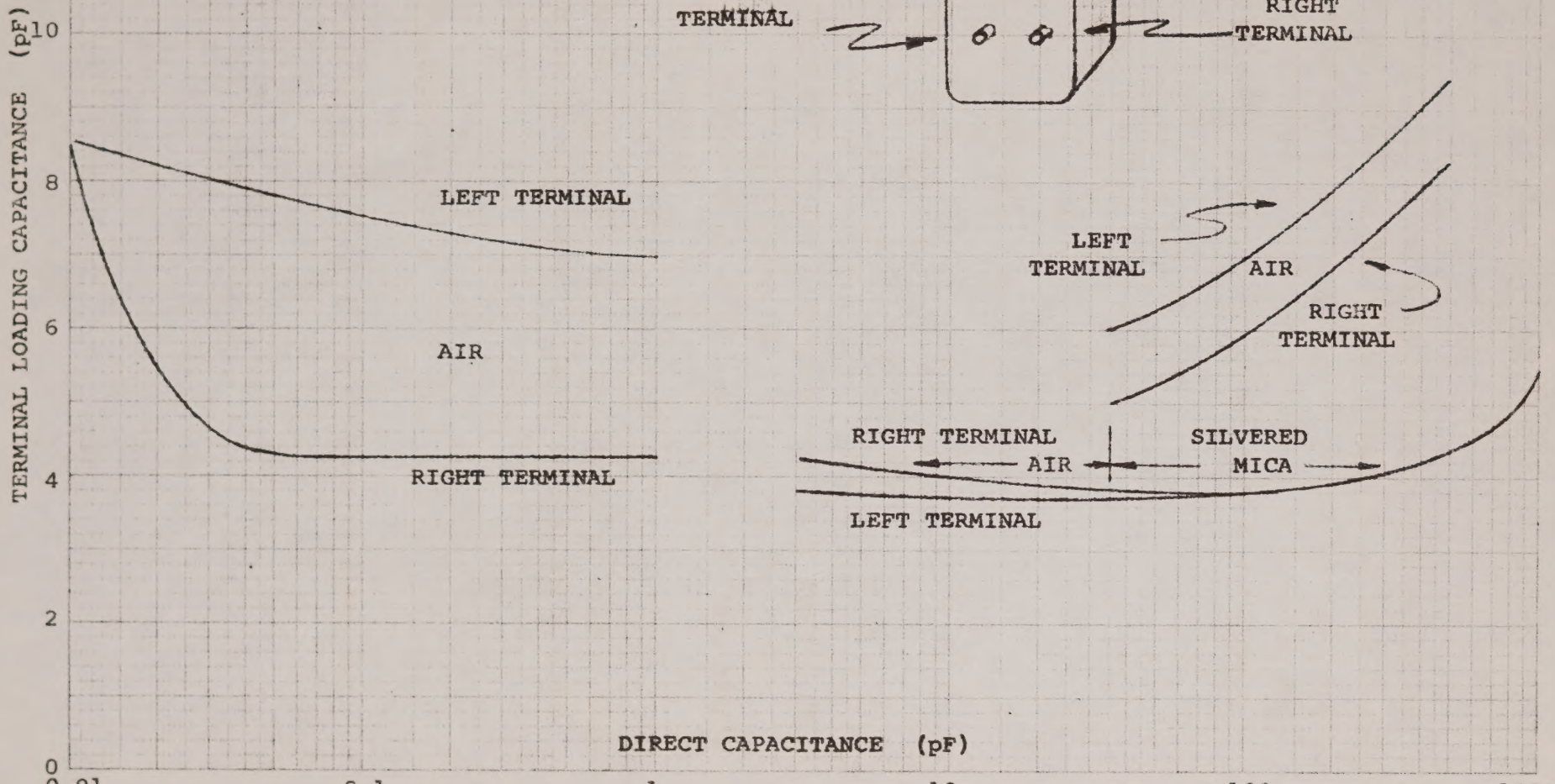
3.4 Shunt Loading Capacitance

Nominal values of shunt loading capacitance are shown in Figure 6.

NOMINAL VALUES OF TERMINAL LOADING CAPACITANCE
OF 76-1A TYPE CAPACITANCE STANDARDS

FIGURE 6.





ВОЗМОЖНЫЕ ЗАРЯДЫ ЧАСТИЦ ГЛИНЫ ВЫЗЫВАЮТ ДВОЙНОЙ СЛОЙ ВОКРУГ ЧАСТИЦЫ

ФИГУРА 8.

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